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# A STUDY OF THE CLERID,

# ENOCLERUS LECONTEI WOLCOTT,

# AS A FACTOR IN THE CONTROL OF THE WESTERN PINE BARK BEETLE

by

HUBERT L. PERSON

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+ C Research Series

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# A STUDY OF THE CLERID, ENOCLERUS LECONTEI WOLCOTT, AS A FACTOR IN THE CONTROL OF THE WESTERN PINE BARK BEETLE

by H.L. PERSON

## INTRODUCTION

The present method used in the control of the western pine bark beetle, Dendroctonus brevicomis Lec.--that is, the felling of the infested trees and peeling and burning the bark--while of proven value under many conditions, is costly, of limited practical application, and even where immediately successful usually gives only temporary relief. Because of these disadvantages of our present methods, studies were started in 1922 to determine the possibilities of biological control through the use of parasites and predators.

The introduction of beneficial insects from other regions is hardly to be considered in this instance. The western pine beetle is a native insect with a complete associated fauna, including a number of predators and probable parasites as well as many secondary insects, scavengers and others of unknown habits. There are probably few areas with a more complete fauna of scolytids and associates than that in which the western pine beetle is found, so that the desirability of establishing exotic species in this association would be questionable even if possible.

Our work has therefore been confined to a study of native species which might be used to supplement direct control operations, the aim being not to discard entirely our present methods, but rather to modify them so as to protect as far as possible the beneficial insects instead of destroying them with our enemy, the western pine beetle.

The present study was started late in 1922 and continued through 1923 in connection with the Southern Oregon-Northern California Control Project. During 1926 and 1927 the work was continued as one of the Cascadel studies near Northfork, Calif., and supplementary data were obtained on the Modoc area of northeastern California in 1928 and 1929.

Preliminary studies, which included field observations, rearing all insects from western pine beetle-infested bark, and the shaving up of hundreds of square feet of similar bark, have shown the parasites to be of comparatively little importance. A few parasitic species are almost always found associated with D. brevicomis, but not in sufficient numbers to be of much importance. There are also associated with D. brevicomis a large number of beetles that vary from the typically predacious to the doubtfully predacious; but only two were found to be of real importance in the control of this scolytid. An important limitation on the number of effective predators is the fact that the D. brevicomis larvae start boring out into the bark soon after hatching. Because of this habit only those predators that are bark-boring forms can follow the broods and prey upon them. This narrows the list of effective insect predators on D.brevicomis broodsddown to the black-bellied clerid (Enoclerus lecontei Wolc.) and the green ostomid (Temnochila virescens (Fabr.) var. chlorodia (Mann.)). Only the clerid will be considered in this paper.

## ENOCLERUS LECONTEI WOLCOTT

This clerid was selected for intensive study because the preliminary work done on the predacious insect enemies of the western pine beetle show that it is by far the most important. It is probably less prolific and less voracious than the ostomid, but it is approximately four times as abundant on infested yellow pine, the adults are more active and so better adapted to preying on the D. brevicomis adults, and in the western yellow pine belt of California and southern Oregon it feeds almost exclusively on this scolytid. The ostomid will feed on almost any of the insects found on infested yellow pine, including beneficial insects, and is even cannibalistic in the larval stage; but in the area mentioned E. lecontei is closely associated with D. brevicomis in all stages and seldom feeds on other insects.

The studies will be considered under three headings. The first deals with the biology of the clerid, especially its life history and habits in their relation to D. brevicomis; the second treats of its importance as a natural control factor, and the third shows how our knowledge of the habits of this beetle may be applied in improving our artificial control methods.

### Historical

Enoclerus lecontei (Thanasimus nigriventris) was described in 1861 by John LeConte[1] from specimens collected near Fort Colville in northeastern Washington and from the Bitterroot Valley, Montana. He refers to it as a species of coleoptera inhabiting the Pacific district of the United States. It was placed in the genus Enoclerus by Wolcott[1] in 1922; and because nigriventris was already occupied in this genus the new name Enoclerus lecontei Wolcott was adopted. The larva was described under this new name by Böving[1] in 1928.

The clerids in general are well-known throughout the world as important predators, but although there is a considerable amount of literature on many of the species, little has been published on E. lecontei. Hopkins has never published on E. lecontei, but he has written a number of articles on both Thanasimus dubius Fabr., a common eastern clerid, and the European bark beetle destroyer, Thanasimus formicarius (Linn.), which he introduced from Europe in an attempt to control D. frontalis and some of its associates. The feeding habits of both these clerids are evidently about the same as those of E. lecontei. The feeding habit of the adult is well illustrated in Bulletin 83--"Bark Beetles of the Genus Dendroctonus" (p.71) by Hopkins[1]--and described in an article in the Canadian Entomologist in 1893 (Hopkins[2]).

Champlain[1] in 1921 summarized the notes of Webb, Hopkins, Fiske, Burke and Champlain, which are found in the office of the Forest Entomologist, Bureau of Entomology. He reports the adults as predacious on Ips, Pityophthorus and Dendroctonus. The feeding of an adult on an adult D. ponderosae is also described and a few life history notes are given. He states that the eggs are deposited in the entrance galleries of the host. This does not agree with my observations. Oviposition has been observed a number of times, and hundreds of E. lecontei eggs have been found on yellow pine infested with D. brevicomis. In every case the eggs were deposited beneath the outer bark scales and in no case were they ever found in the entrance galleries. It may be found that this clerid varies its egg-laying habit with the bark beetle with which it is associated.

A more recent reference to E. lecontei is in an article by F.M. Trimble[1], in which he reports this clerid as one of the natural enemies of Ips radiatae Hopk. and Ips plastographus Lec. in the Monterey pine area of the central coast region of California. This is the only record we have of E. lecontei on Pinus radiata.

Keen[1] in a recent publication reports E. lecontei as the most active enemy of the western pine beetle (D. brevicomis).

Other references to E. lecontei are found in the unpublished notes of Miller, Keen, Burke, Patterson and Person at the Palo Alto, Calif., station of the Bureau of Entomology, Office of Forest Insect Investigations. Miller reported the adults as predacious on D. brevicomis near Ashland, Oreg., in 1914. Since then Patterson, Keen, Burke, Wagner and Sergent, as well as the writer (all of the Bureau of Entomology) have reported this insect as associated with D. brevicomis and in a number of cases actually feeding on this scolytid. Mr. Edmonston, also of the Bureau of Entomology, found E. lecontei very abundant near Prescott, Ariz., where it was associated with D. barberi, D. approximatus, D. convexifrons and D. arizonicus.

In the article by Böving and Champlain[1] previously referred to, Böving described a large number of clerid larvae, but because of a lack of authentic material the larva of E. lecontei was not described at that time. The writer sent some larval material to Böving in 1923, and on the basis of this material he has written the description of the larva already referred to (Böving[1]). A mistake was made, however, in describing the color of the mature larva, because it was based on the color of specimens in alcohol. The principal body color is a reddish-purple instead of pink, as given in Böving's description.

The following details of its life history and habits were worked out by the writer in the vicinity of Klamath Falls, Oregon, in the summer of 1923, and at Cascadel, at an elevation of 3,500 feet, on the Sierra National Forest of California, during 1926 and 1927, supplemented by observations throughout the yellow pine belt of California and southern Oregon from 1924 to 1929. These observations were limited exclusively to the association of N. lecontei with D. brevicomis on the western yellow pine, Pinus ponderosa Lawson.

## Life History and Habits

### Oviposition

In searching for a suitable place to oviposit, the female runs nervously about on the bark of an infested tree, stopping frequently to feel under an outer bark scale with the ovipositor. When a satisfactory place is found the ovipositor is inserted about one-eighth inch into the minute opening between the bark scales, and the eggs are laid. Usually from two to five eggs are laid in a single group, but as many as ten have been found, closely fitted together into a single-layered mat.

Caged clerids oviposited on the outside of the bark with no attempt at concealment; but under natural conditions they are always hidden so that it is necessary to flip off the outer bark scales to find them.

The total number of eggs laid by each female has not been determined, but it is believed that 20 to 30 would be a fair estimate. Eggs are laid during the day, the adults being most active on bright, warm days. In July, 1929, the number of eggs per female was checked by the dissection of gravid females by Struble. He found from 15 to 40 mature and immature eggs per female, with the average around 25.

## The Egg

The eggs are light pink in color, with a circular white band near the smaller end. The length is between .05 and .07 inches and the width between .014 and .018 inches. The shape is elongate ovoid, with a slightly curved longitudinal axis and a more gradual taper toward the smaller end. There are no surface markings. (See Figs. 1 and 2) The incubation period is about 10 to 14 days under average field conditions.

## The Larva

When the larva is ready to emerge, it twists about until the egg splits open anterior to the head, and the larva works itself out by continual twisting and bending. The young larvae are pink in color, with the chitinized parts dark brown. After freeing themselves from the eggshell they crawl about on the bark until a suitable crack is found, into which they disappear.

Within a short time they work their way through the bark, taking advantage of cracks and the ventilation holes of the western pine beetle, and are next found in the phloem, or inner bark. Here they begin feeding on the newly-hatched D. brevicomis larvae. As the latter develop they work out toward the outer bark, where they finally pupate. The clerid larvae work outward with them, boring their way from one larval tunnel to another, killing and consuming a part or all of the victims, with the exception of the chitinized parts. They feed readily on D. brevicomis larvae and pupae and occasionally on a newly-formed adult, but will not feed on the adults after the chitinized parts have begun to harden.

By the time the D. brevicomis brood has completed development, most of the clerid larvae have reached the mature larval stage. A variable percentage, usually from 40 to 90, of these clerid larvae bore out through the bark and crawl to the base of the tree. Here they either pupate in the outer bark scales near--either a little above or a little below--the surface of the ground, in the ground, or in sticks or pieces of bark in the duff, usually near the surface of the mineral soil. The other 10 to 60 per cent pupate in the outer bark scales near where they stopped feeding.

The mature larvae hollow out flattened ovoid cells and line them with a white, silvery substance. These cells are quite characteristic, and are easily distinguished even after the clerids have emerged from them (see Fig. 3).

The larval stage of the individual is between 50 and 60 days for those developing during the summer, and from 5 to 7 months for those that overwinter. The pupal period of the individual is about 6 to 14 days.

The Adult

The adults emerge within a few days after completing their development and are ready to fly to a newly-attacked D. brevicomis tree.

They are found running about on newly-attacked living trees, windfalls or slash, where they capture and feed upon the attacking bark beetles, mate and lay their eggs.

## Feeding Habits of Adults

As the adult clerids like the sunlight and usually feed in the open, their feeding habits are easily observed. The clerid moves about very rapidly over the bark, and when it encounters a bark beetle it seizes the victim with its four anterior legs, balancing itself on its two posterior legs and the tip of the abdomen. Regardless of the position of the scolytid when captured, the clerid always turns it so that their venters are opposed and their heads face in the same direction. The point of attack is usually at the juncture of the head and thorax or of the thorax and abdomen. Feeding habits are similar to T. formicarius (see Hopkins [1]). The amount of the beetles actually consumed varies from a small part of the soft internals to practically all the body except the wings and more heavily-chitinized parts.

Feeding experiments were conducted to determine the "beetle-day" consumption of E. lecontei in comparison with other predators of D. brevicomis adults under caged conditions.

Large glass jars containing pieces of yellow pine bark were used for the study. A number of E. lecontei and D. brevicomis were put into one of these jars and a count made of the total number of D. brevicomis killed and at least partially eaten. From these studies it was found that the "beetle-day" consumption of the clerids was .6d.

From field observation it appears that this is a conservative figure.

On nearly all D. brevicomis-attacked trees of the first summer generation the adult clerids are quite conspicuous, as they run about over the bark in search of western pine beetle adults, upon which they may commonly be seen feeding.

In many cases of newly-attacked trees the clerid adults are the most noticeable evidence of an attacked tree, especially in the case of trees which are not attacked near the base.

On many trees the clerids are so abundant that their importance in the natural control of D. brevicomis is unquestionably very great. This was particularly true on the Badger Springs Unit of the Modoc National Forest in the summer of 1928. Hundreds of clerids were seen on nearly every infested tree; and it is believed that the very pronounced decline in infestation between the 1928 summer and winter generations was largely the result of this unusually heavy concentration of clerid adults.

The life of caged adults averaged about 40 days, and it is probable that under natural conditions the adults would live at least six weeks or two months.

## Life History

The life history of E. lecontei was worked out in its relation to that of D. brevicomis. It is quite complicated because of the overlapping of generations, so that it could not be satisfactorily worked out in the one summer spent in southern Oregon. At Northfork the life history was followed for two years, so that a satisfactory life history chart has been worked out for that locality (see Fig. 4). The principal method used in working out life histories was to locate a number of trees when first attacked, and follow the development of the broods by shaving up sample sections of bark at frequent intervals and noting the stage of both D. brevicomis and the clerids.

Locating newly-attacked trees was simplified by caging the lower trunks of certain trees and forcing attacks into those caged sections. This usually attracted beetles to the uncaged part of the trunk and a normal development followed. The brood development in these sample trees was checked with a large number of observations on other trees, many of which were felled to make possible the bark analysis of the entire trunk. The chart (Fig. 4) shows the rate of development of E. lecontei broods for each of the three D. brevicomis generation trees for 1926 and 1927.

It was found that in the lower yellow pine belt of the southern Sierra Nevadas at Northfork, Calif., there are three fairly distinct generations of D. brevicomis. The D. brevicomis life history is shown in broken lines and that of the clerid in solid lines. It may be seen that while the D. brevicomis adults emerging from the first-generation trees make the second-generation attack in July and August, and the emerging adults from the second-generation D. brevicomis trees make the third-generation attack in September and October, this is not true of the clerids. The development of the clerids is so much slower that only a very few of the brood on first-generation trees emerge in time to lay their eggs on second-generation D.b. trees, the largest percentage (of the brood from first-generation trees) attack third-generation trees, and a small percentage overwinter as prepupal larvae at the base of the trees and do not emerge until the following spring.

From the second-generation D.b. trees only a small percentage of the clerids emerge in time to lay their eggs on the third-generation D.b. trees. About 80 to 90 per cent of the clerids overwinter as prepupal larvae and emerge the following spring. Both the D. brevicomis and the clerid broods overwinter as eggs or larvae in the third-generation D. brevicomis trees, but the clerids emerge a month or two later the following year.

It is evident from the above that while there are three fairly distinct generations of D. brevicomis, there are not more than two generations of E. lecontei at Northfork, Calif.

Figure 5 is a quantitative graph of the life history for the clerids on the 1926 D.b. trees. It shows roughly the peaks for the different stages, the relative importance of the partial broods and the abundance of clerids on the three D. brevicomis generation trees. This last point will be discussed later to show its importance in artificial control operations. Figure 6 shows the comparative abundance of different stages of E. lecontei for Generations II and III, 1926.

Of course the rate of development for both D. brevicomis and E. lecontei would vary in different localities, and for different seasons in the same locality. It will be noted that the broods were later in 1927 than in 1926 at Northfork, no doubt due to the cold spring of 1927.

In the Klamath Falls region of southern Oregon, D. brevicomis has at the most only two or two and one-half generations, and the E. lecontei generations are correspondingly reduced.

Importance of E.lecontei in the Natural Control of D. brevicomis

The object of this part of the study was to determine by quantitative methods the effect of E. lecontei on D. brevicomis broods under natural conditions.

Procedure

The field studies were carried on in connection with caging experiments with D.b. on resistance and attraction. In this work from 15 to 20 feet of the base of six yellow pine trees was caged and an attack started by introducing D.b. adults into these cages. The cages were four feet square and built of surfaced 2x4 material covered with 16- or 18-mesh wire screen. The screen was tightly fitted on all seams and around the trunk of the tree above the frame, so that the caged D.b. could not escape, nor could other insects get into the caged part of the tree (see Fig. 7). The trees used were between 20 and 30 inches in diameter and from 100 to 140 feet in height.

The attack was started on the three trees used in 1926 and one of the trees used in 1927 by putting yellow pine bark infested with D.brevicomis new adults in the cages. As the beetles emerged they attacked the trees, since the cage kept them from escaping. It was found that the emergence of D. brevicomis from this infested bark was completed and the trees killed before the emergence of the predators. Taking advantage of this fact, all the bark was removed from the cages as soon as most of the bark beetles had emerged, and the caged part of the tree was kept practically free from clerids; while the part of the tree above the cage was exposed to the normal action of both D. brevicomis and the clerids. In the other two cages only the D. brevicomis adults collected from rearing cages were used, so that these two cages were kept entirely free from predators. Then by comparing the number of clerids and the number of D. brevicomis at different stages in their development in sample areas just inside the top of the cage with similar areas just outside the top of the cage, it was possible to determine the effect of the clerids. The study of these six trees was supplemented by bark counts and observations from a number of other trees, both caged and uncaged, but especially from trees that were attacked naturally.

The development of the broods within the bark was followed by carefully shaving up and examining the contents of sample areas of the bark. These brood counts were made at three different stages. The first count was made when the D. brevicomis broods were in the small larval stage, the second count at the prepupal larval stage, and the third count shortly after the D. brevicomis had emerged, at which time E. lecontei would be in the mature larval stage. On some of the trees the first count was not made. For the first count usually only one square foot of bark was used inside and one square foot above the cage. For the other two counts, strips one foot in width and extending completely around the trunk were shaved up, one inside and one above the cage.

All the samples counted, both inside and outside the cage, were taken as near the top of the cage as possible, so that differences in the diameter of the tree, bark thickness etc. inside and above the cage were minimized. This was the ideal condition, which was not completely realized; exceptions will be noted.

## Results

The results of these counts are given in Table 1. The data for some of the trees are incomplete because it was not possible to make the necessary counts, due to lack of time. The larval count for K1-2 inside the cage was arbitrarily increased from 203 to 300, because on the basis of other counts made it was obviously abnormally low. This is explained by the fact that this count was made at only 5 feet above the base, at which height the brood is almost always smaller than at 15 feet above the base, where the emergence count was taken.

The effect of the clerids, aided to a limited extent by other natural enemies of the scolytid, is more clearly shown by Figs. 8 and 9. In Fig. 8 the D. brevicomis brood reduction from the large larval stage to emergence inside the cage is compared with the brood reduction outside the cage on trees J-4, T-6, K2-I and K1-II. (The letter J signifies trees killed in 1926 and the letter K trees killed in 1927.) Fig. 8 shows a striking difference in brood mortality inside the cage where the clerids and other large predators were excluded, and outside, where clerids were quite abundant. Fig. 9 shows the effect of the predators on the total emergence.

Tree K3-II received treatment different from the others. The trunk was separated into halves longitudinally by shaving two smooth strips on opposite sides of the tree, caging each half with a four-foot width of fine-mesh screen and tacking it with wooden strips, so that the insects from one side could not get into the other. The top and bottom of each side were fitted closely around the trunk and made insect-tight by the use of cotton batting (see Fig. 10).

An equal number of D. brevicomis adults (4,000) was released in each side of the cage, and 50 E. lecontei adults were released on one side, the other being kept free of predators.

This gave three different areas for comparison on the same tree--the south side of the tree with no predators, the north side with 50 E. lecontei adults (about one per square foot), and above the cage the number of clerids found naturally. The results show the effect of the clerids on the emergence of D. brevicomis, but the concentration of clerids above the cage was less than is usually found, so that the differences are not so great as they might have been.

Aside from the difference in the emergence of D. brevicomis inside and outside the cages, which may be partly due to other factors, it is apparent that the large number of clerids found in infested bark outside the cages would have a pronounced effect in reducing the bark beetle broods. From the feeding studies it was found that the average E. lecontei larva destroyed more than .5 D. brevicomis per day; so that from 5 to 37 clerids feeding for a period of at least two or three weeks would be a very important factor in brood reduction.

This beneficial effect would be continued in the adult stage, and it is evident that trees from which the D. brevicomis emergence is only about twice as great as the emergence of clerids would provide enough predators to more than account for the bark beetles that emerged from them, since feeding studies showed that each clerid adult might easily destroy 25 or 30 D. brevicomis adults.

Although the effect on brood reduction shown in the preceding cannot be credited entirely to E. lecontei, analyses of the bark contents show that this clerid is undoubtedly the principal factor. Since the parasites are so small that they were not kept out of the cages by the screen, the only insects beside the clerids that effected the brood reduction outside the cage, and not inside, are the ostomid, T. virescens var.chlorodia, and possibly cerambycids. As the cerambycids affect only the very small larvae while in the phloem, their effect would not show up in brood reduction--because no counts were made in this small-larva stage--though it would in emergence. The ostomid is a factor of some importance, but the bark counts showed that it was only about one-quarter as abundant as the clerid; and as it feeds to some extent on clerids and other beneficial insects as well as on the D. brevicomis broods, it is of much less importance than the clerids.

Referring again to Table 1, the difference in the number of clerids per square foot on different trees is quite remarkable, varying from two on I-5 to 37 on K2-I. The reason for this is not known, but it is believed that it may be due to the time of attack of D. brevicomis. Apparently the first tree to be attacked within a local area attracts most of the clerids that are near, and consequently it has a greater number than trees attacked soon afterward. This holds true for all the caged trees on which the exact time of attack was known. It has been noticed that the heaviest concentration of clerids found has been on the caged trees. Evidently there is something about the method of starting attack or the large number of D. brevicomis used that attracts a greater number of clerids than are found on naturally-attacked trees. In spite of this, the number of clerids found with D.brevicomis broods in trees normally attacked averages about as high as it does in the caged trees, and the effect of E. lecontei under natural conditions is probably as great as has been shown for the caged trees. This belief is supported by emergence counts from hundreds of square feet of bark, from which it is found that the emergence from normally-attacked trees averages about the same as the emergence from the uncaged part of caged trees.

Table I

Effect of E. leconteï on D. brevicomis Broods

1926

| Tree No. | Inside Cage: Basis #sq.ft. | D.b.per sq.ft. | E.l.per sq.ft. | Decrease D.b.Broods No. | Decrease D.b.Broods % | Above Cage: Basis sq.ft. | D.b.per sq.ft. | E.l.per sq.ft. | D.b.Brood Mortality No. | D.b.Brood Mortality % |
|---|---|---|---|---|---|---|---|---|---|---|
| J-4 | | | | | | 1 | 443 | | | |
| | 8 | 133 | 5 | | | 7.8 | 42 | 22 | 401 | 90 |
| J-5 | | | | | | 1 | 196 | 2 | | |
| | 1 | 336 | 1 | | | 1 | 98 | 2 | | |
| | | | | | | 5.6 | 36 | 2 | 82 | 65 |
| J-6 | 1 | 112 | 0 | | | 1 | 238 | | | |
| | 6.5 | 73 | 1.3 | 39 | 35 | 1 | 50 | 5 | 188 | 79 |

1927

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| K2-I | 7.8 | 365 | 0 | | | 2 | 309 | | | |
| | | | | | | 4.4 | 229 | | | |
| | 2 | 247 | 0 | 118 | 32.2 | 4 | 76 | 37 | 233 | 75 |
| K1-2 | 6 | 300* | 1 | | | 6.4 | 220 | 15 | | |
| | 5.5 | 191 | | 109 | 36.3 | 5.0 | 54 | | 166 | 75 |
| K-3 | | | | | Oside | 2 | 230 | | | |
| | | | | | No.E.l. | | | | | |
| | | | | | N.side | 2 | 212 | | | |
| | | | | | 50 E.l. | | | | | |
| | | | | | Outside | 2 | 151 | | | |
| | | | | | Normal | | | | | |

*Estimated; actual no. 203

Protecting E. lecontei on Control Operations

This phase of the study, which is of most importance from the economic standpoint, is far from complete, and should be the object of further study. At present two recommendations can be made on the basis of certain known facts concerning the habits of this clerid:

1. In general, control work by the regular burning method should not be directed against the summer-generation D. brevicomis trees because of the large number of clerids on these trees.

This concentration of clerids on the first-generation D.brevicomis trees was suspected because of the "hang-over" until the following spring of a small percentage of the larvae from the first-generation trees and a large percentage of the larvae from second-generation D. brevicomis trees. Because of this habit we have during April to July of any year clerids emerging from all the D. brevicomis trees killed the preceding summer (see Life History Chart, Fig. 5).

To check this point and determine how the number of clerids compared in the different generations of D. brevicomis trees, over 500 square feet of infested bark was shaved up and all the clerids counted. Most of these counts were made during 1926 and 1927.

The results are given in Table 2, and the difference in abundance of clerids for the three generations is shown graphically in Fig. 11. This proportion is also shown roughly in Life History Chart (Fig. 5). Since the results obtained in 1927 check very well with the 1926 results, it is probable that this proportion is fairly constant. The counts from the third-generation trees do not have as good a basis as the other two generations, but check very well with what we should expect from the life history studies.

These data are sufficient to prove the danger of general control work on the early summer trees, which may have as many as 30 clerids per square foot for the entire tree, or up to 50 in a single square foot. Since such large numbers of clerids would more than account for the number of D. brevicomis that emerged from these trees, it seems evident that artificial control work as usually performed--felling the trees and burning the bark--would do as much harm as good, and probably more harm than good on many of the trees.

The only summer control work that was done on the Southern Oregon-Northern California Project proved very ineffective in comparison with the work on the overwintering broods and the destruction of a large number of clerids--which constitute the most effective check on the increase of the D. brevicomis missed in the control work--was probably a major reason.

In general, then, artificial control work as now practiced should be concentrated on trees containing the overwintering D.brevicomis broods, since such trees contain the smallest number of E. lecontei.

Table 2

Abundance of E. lecontei by Generations

Normal Broods Outside of Cages - Before Migration

Generation I

| | Basis No. Trees | No. Sq.Ft. | Total No. E.l. | | E.l. per sq.ft. |
|---|---|---|---|---|---|
| 1926 | 5 | 155.0 | | | 11.80 |
| 1927 | 10 | 191.8 | 2332 | | 12.16 |
| Total | 15 | 346.8 | | Av. | 11.83 |

Generation II

| | | | | | |
|---|---|---|---|---|---|
| 1926 | 6 | 114.0 | | | 6.50 |
| 1927 | 4 | 23.5 | 136 | | 5.79 |
| Total | 10 | 137.5 | | Av. | 6.14 |

Generation III

| | | | | | |
|---|---|---|---|---|---|
| 1922 | 1 | 18 | 71 | | 3.94 |
| 1926 | 1 | 15.5 | 40 | | 2.58 |
| 1927 | 2 | 6 | 16 | | 2.66 |
| | 4 | 39.5 | 127 | Av. | 3.22 |

2. The bases of infested trees should be protected from control fires in order to save any clerid larvae that might have migrated before the trees were treated.

This migratory habit of the mature larvae has been known for a number of years and the writer, during 1926 and 1927, determined the approximate percentage that migrates for each of the three D. brevicomis generations found at Northfork, Calif.

This was found by making comparative counts of the number of clerids in a square foot of bark before and after pupation. The results are given in the following table (3) and shown graphically in Figs. 12 and 13. No reason can be given for the variation in the number that migrated--from 44 to 93 per cent. It is probable that this would vary for different years, and it is known to vary for different trees in the same year. The data may be inadequate as a basis for comparing the amount of migration by generations, but are sufficient to show that a very large percentage of clerids do migrate.

These mature larvae pupate in the outer bark at the base of the tree near, or from one to four inches beneath, the surface of the ground litter; in pieces of bark, twigs and other litter, and in the soil itself. Many of the larvae probably crawl some distance from the base of the tree, as the total number found there is never sufficient to account for the total number that must have migrated. As many as 125 prepupal larvae have been found at the base of a single tree.

The number of clerids saved by protecting the bases of the treated trees depends on the abundance of the clerids and the stage of the brood at the time the tree is treated. Since none of the larvae migrates normally until mature, it is evident that the more advanced the brood is at the time of treating, the greater the percentage of clerids saved. On trees in which the D. brevicomis broods had reached the adult stage, most of the migration would have occurred and a large percentage of the clerids would be saved.

Table 3

Migration of E. leconteï

| | | Basis | | E.l. per sq.ft. | | Decrease per sq.ft. | |
|---|---|---|---|---|---|---|---|
| | | Trees | No.sq.ft. | Before-Migration-After | | No. | % |
| Gen. I | Before migration | 15 | 343.8 | 11.88 | | | |
| | After migration | 2 | 16. | | 6.6 | 5.28 | 44.4 |
| Gen. II | Before mi. | 10 | 137.5 | 6.14 | | | |
| | After mi. | 9 | 28 | | .856 | 5.284 | 86.2 |
| Gen.III | Before mi. | 1 | 33.5 | 3.32 | | | |
| | After mi. | 14 | 88.5 | | .23 | 3.09 | 93.1 |

E. lecontei in Relation to Biological Control

The motility of the clerid larvae and their migratory habit in the mature larval stage suggested the possibility of exposing infested logs so that a high percentage of the broods of the western pine beetle would be destroyed without injury to the clerids.

Some work was done on this part of the study on the Modoc National Forest during 1928 and 1929. Only a brief summary of the work is included here, as the details are covered in a recent report (Person[1]) and will also be included in a later paper after the work has been more fully developed.

In 1928 most of the work was concentrated on the comparative effects of exposure under different conditions on the broods of the western pine beetle and the clerid. In 1929 the studies were continued, with emphasis on the relation between air temperatures and bark temperatures and the effect of known bark temperatures on the mortality of D. brevicomis and E. lecontei.

As a result of the two seasons' work on this part of the study, the following conclusions appear to be justified:

1. Bark temperatures on the top and upper sides of logs exposed to direct sunlight, under favorable field conditions, were found to run well above the point known to cause mortality in D. brevicomis broods.

2. The actual mortality of D. brevicomis was found to agree quite closely with what was expected on the basis of the study of bark temperatures.

3. No mortality of clerids was found, even where 100 per cent of the D. brevicomis broods died as a result of high temperatures.

4. The mortality of D. brevicomis on the sides and bottoms of exposed logs is apparently much higher than infested trees which are left standing, probably because of less favorable moisture and temperature conditions and the concentration of clerids driven from the upper parts of the logs by high temperatures.

5. This method of control would be applicable only on the summer-generation trees in which the clerids are normally abundant. Its effectiveness would also be limited to areas with fairly open stands and gentle slopes or favorable exposures, such as are found over large areas in the western yellow pine type of southern Oregon and northern California.

(Work on this part of the study is being continued.)

## SUMMARY

This report assembles in preliminary form the results of seven years of study by the writer of the clerid, N. lecontei Wolc., as a natural enemy of the western pine bark beetle, supplemented by a study of the notes, published and unpublished, of other workers who have contributed to our knowledge of this subject.

Although there are a few parasites and a number of more or less typically predacious insects associated with D. brevicomis, few of them are of real importance in its control. The habits of the larvae of this bark beetle, which develop out in the bark rather than under the bark as so many of its associates do, limits the predators on this stage to the bark-boring forms which can tunnel about in the bark in their search for prey. There are only two predators which are not affected by this limitation--the clerid, Enoclerus lecontei, and the ostomid, Temnochila virescens var. chlorodia.

The life history and habits of T. virescens, chlorodia were worked out in some detail. It was found to be of some importance in the natural control of D. brevicomis, but its value is lessened by the fact that it feeds on beneficial insects as well as on the injurious bark beetles.

The clerid, E. lecontei, is undoubtedly the most important insect enemy of the western pine beetle, and so was made the principal object of this study. When associated with D. brevicomis it feeds almost exclusively on this scolytid; it has never been reported as feeding on beneficial insects, and is about four times as abundant as the ostomid, its closest competitor.

This study included a detailed study of the life history and habits of this clerid (E. lecontei) and a consideration of its importance and the possibilities of increasing its effectiveness by modifications in the methods used in the control of D. brevicomis. The following points were brought out in this study:

1. E. lecontei is closely associated with D. brevicomis throughout its life history and is predacious on it in both the larval and adult stages.

2. The larvae vary in number from 2 or 3 per square foot of D.brevicomis-infested bark to as many as 50 per square foot. They are most abundant on the first-generation (D. brevicomis) trees and least abundant on the overwintering trees.

3. It was found that where the clerid larvae were abundant the brood mortality of D. brevicomis was more than twice as great as where the clerids were excluded.

4. The clerid adults are probably even more important in natural control than the larvae. They are usually abundant, particularly on newly attacked summer-generation D. brevicomis trees, and may be commonly seen seizing and feeding on the attacking western pine beetle adults.

5. Two suggestions can be given for protecting clerids on control operations:

a. In general, the burning method of control work should not be directed against the summer-generation D. brevicomis trees because the clerids are usually two or three times as abundant on these as on late summer or winter generation trees.

b. Because a large percentage of the mature clerid larvae migrate to the base of the tree, the bases of treated trees should be protected from control fires.

6. The motility of the clerid larvae in all stages and the migratory habit in the mature stage suggested the possibility of saving a much larger proportion of the clerids on control operations by felling infested trees and exposing the trunk to full sunlight.

Preliminary studies show that it is possible, under favorable field conditions, to kill nearly 100 per cent of the D. brevicomis broods on the upper sides of infested logs without any evidence of injury to the clerids.

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